

of the logarithm sine of half that arc, rejecting the indices.

But, as these differences give the divisions to the supplements of the real versed sines; therefore the arithmetical complement of the logarithm sine of any arc being doubled, will give the distance of the division for the supplement of twice that arc on the line of versed sines.

Thus, for 70° , the logarithm sine is 9,97299

The arithmetical complement is 0,02701

Its double is 0,05402

Which is the number in the foregoing table standing against 140° , and is the supplement versed sine of twice 70 degrees.

Now, as the arithmetical complements of the log. fines of arcs, are the distances on the line of sines between 90° , and the divisions to those arcs; therefore the distances between 90° and any arc, being twice repeated, will give the division of the supplemental versed sine to twice the co-sine of that arc.

XIV. *A Letter from Mr. John Dollond to Mr. James Short, F. R. S. concerning an Improvement of refracting Telescopes.*

S I R.

Read March 1, 1753. **I**T is well known, that the perfection of refracting telescopes is very much limited by the aberration of the rays of light from the geometrical focus; which arises from two very different causes; that is, from different degrees

grees of refrangibility of light, and from the figure of the sphere, which is not of a proper curvature for collecting the rays in a single point. The object-glass is chiefly affected by the first of these; nor has there been yet any method discover'd for rectifying that aberration so, as in the least to remove the indistinctness of the image arising from it. We are therefore reduced to the necessity of contracting their apertures, which renders it impossible to magnify much without very long glasses.

But the case is widely different with regard to the eye-glasses; for, tho' they are very much affected by both the aberrations before-mention'd, yet, by a proper combination of several together, their errors may be in a great measure corrected. If any one, for instance, would have the visual angle of a telescope to contain 20 degrees, the extreme pencils of the field must be bent or refracted in an angle of 10 degrees; which, if it be performed by one eye-glass, will cause an aberration from the figure, in proportion to the cube of that angle: but if two glasses are so proportioned and situated, as that the refraction may be equally divided between them, they will each of them produce a refraction equal to half the required angle: and therefore the aberration being in proportion to the cube of half the angle taken twice over, will be but a fourth part of that, which is in proportion to the cube of the whole angle; because twice the cube of one is but $\frac{1}{4}$ of the cube of two; so the aberration from the figure, where two eye glasses are rightly proportion'd, is but a fourth of what must unavoidably be, where the whole is performed by a single eye-glass. By the same way of reasoning, when the refraction is divided

divided between three glasses, the aberration will be found to be but the ninth part of what would be produced from a single glass; because three times the cube of one is but one ninth of the cube of 3. Whence it appears, that, by increasing the number of eye-glasses, the indistinctness, which is observed near the borders of the field of a telescope, may be very much diminished, tho' not entirely taken away.

The method of correcting the errors arising from the different refrangibility of light is of a different consideration from the former; for, whereas the errors from the figure can only be diminished in a certain proportion to the number of glasses, in this they may be intirely corrected, by the addition of only one glass; as we find in the astronomical telescope, that two eye-glasses, rightly proportion'd, will cause the edges of objects to appear free from colours quite to the borders of the field. Also in the day-telescope, where no more than two eye-glasses are absolutely necessary for erecting the object, we find, by the addition of a third rightly situated, that the colours, which would otherwise confuse the image, are intirely removed: I say intirely removed; but this is to be understood with some limitation; for tho' the different colours, which the extreme pencils must necessarily be divided into by the edges of the eye-glasses, may in this manner be brought to the eye in a direction parallel to each other, so as, by the humours thereof, to be converg'd to a point in the retina; yet, if the glasses exceed a certain length, the colours may be spread too wide to be capable of being admitted thro' the pupil or aperture of the eye; which is the reason, that, in long telescopes, con-

structed in the common manner, with three eye-glasses, the field is always very much contracted.

These considerations, Sir, first set me on contriving, how to enlarge the field by increasing the number of eye-glasses, without any hindrance to the distinctness or brightness of the image: And tho' others had been about the same work before, yet observing, that the five-glass telescopes, sold in the shops, would admit of farther improvement, I endeavour'd to construct one with the same number of glasses in a better manner; which so far answer'd my expectations, as to be allow'd by such persons, as are the best judges, to be a considerable improvement on the former.

Encouraged by this success, I resolved to try, if possibly I might gain some farther enlargement of the field by the addition of another glass: and by placing and proportioning the glasses in such a manner, as to correct the aberrations as much as possible, without any detriment to the distinctness, I have obtained as large a field, as is convenient or necessary, and that even in the longest telescopes, that can be made.

These telescopes with fix glasses having been well received, and some of them being gone to foreign parts, it seems a proper time to settle the account of its origin; which is one of the motives, that has induced me to trouble you with this short sketch of the considerations, that gradually led me to its construction; and I am emboldened, Sir, to write thus much, from the many favours I have already received at your hands, as well as from a sense of your being a proper person to judge in such cases. And tho' I am sensible, that you are not unacquainted with the theory contain'd in this letter, yet for as much

much as the subject has never been fully treated by any author, I shall endeavour, as soon as may be, to draw up a more particular explanation of the aberrations of light by refraction; but shall add no more at present, only beg leave to take this opportunity of subscribing myself

Vine-Court, Feb. 21,
1753.

Your much obliged and
most humble servant,

John Dollond.